Search for 1st Generation Scalar Leptoquarks

Simona Rolli

Outline

- One paper to be submitted to PRL cdf7529
- Outline of the analyses
  - eejj
    - Blessed in March 2003/March 2004
  - $e\nu jj$
    - Blessed in July 2003/August 2004
  - Combination
    - Blessed in July 2003/January 2005

These analyses : lepton signatures only
Combined with: MET + jets (cdf7200 - submitted to PRD)

Theoretical Motivation

- **Leptoquarks (LQ) are hypothetical particles which appear in many SM extensions to explain symmetry between leptons and quarks**
  - **SU(5) GUT model**
  - **superstring-inspired models**
  - **'colour' SU(4) Pati-Salam model**
  - **composite models**
  - **technicolor**

•**LQs can have**:

–spin 0 (scalar)

•couplings fixed, i.e., no free parameters

•Isotropic decay

–spin 1 (vector)

•anomalous magnetic (k_G) and electric quadrupole (λ_G) model-dependent couplings

–Yang-Mills coupling: $k_G = \lambda_G = 0$

–Minimal coupling: $K_G = 1$, $\lambda_G = 0$

–Decay amplitude proportional to $(1 + \cos\theta^*)^2$

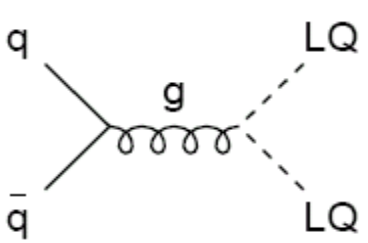
•LQs are **coupled to both leptons and quarks** and carry SU(3) color, fractional electric charge, baryon (B) and lepton (L) numbers

- **Experimental evidence searched:**
  - **indirectly: LQ-induced 4-fermion interactions**
  - **directly: production cross sections at collider experiments**

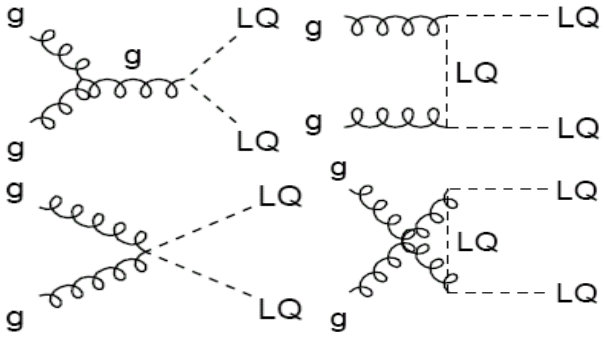
LQ Production

- **Pair production**
  - Practically independent of Yukawa coupling _ (only g-LQ-LQ vertex)
  - Depends mainly on LQ mass

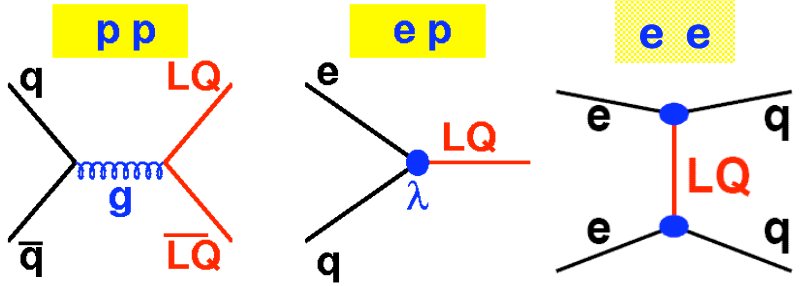
$q\bar{q} \rightarrow LQ\ LQ$



$gg \rightarrow LQ\ LQ$



Comparison with other machines



LQ Decay

$\beta = Br(LQ \rightarrow lq)$

Each generation can decay into 3 final states:

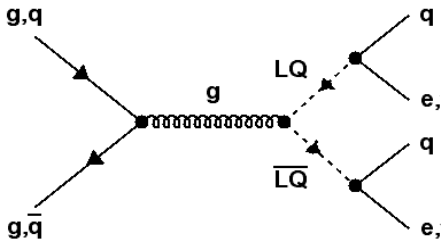
Exclusive to the Tevatron

	1st Generation	2nd Generation	3rd Generation
$\beta = 1$	$LQ\,\overline{LQ} \rightarrow e^- e^+ q\bar{q}$	$LQ\,\overline{LQ} \rightarrow \mu^+ \mu^- q\bar{q}$	$LQ\,\overline{LQ} \rightarrow \tau^+ \tau^- q\bar{q}$
$\beta = 0.5$	$LQ\,\overline{LQ} \rightarrow e^{\pm} \nu_e q_i q_j$	$LQ\,\overline{LQ} \rightarrow \mu^{\pm} \nu_\mu q_i q_j$	$LQ\,\overline{LQ} \rightarrow \tau^{\pm} \nu\, q_i q_j$
$\beta = 0$	$LQ\,\overline{LQ} \rightarrow \nu_e \nu_e q\bar{q}$	$LQ\,\overline{LQ} \rightarrow \nu_\mu \nu_\mu q\bar{q}$	$LQ\,\overline{LQ} \rightarrow \nu_\tau \nu_\tau q\bar{q}$

This paper!

$LQ\,LQ \rightarrow llqq$	2l+2j	$BR = \beta^2$
$LQ\,LQ \rightarrow l\nu qq$	l+MET+2j	$BR = 2\beta(1-\beta)$
$LQ\,LQ \rightarrow \nu\nu qq$	MET+2j	$BR = (1-\beta)^2$

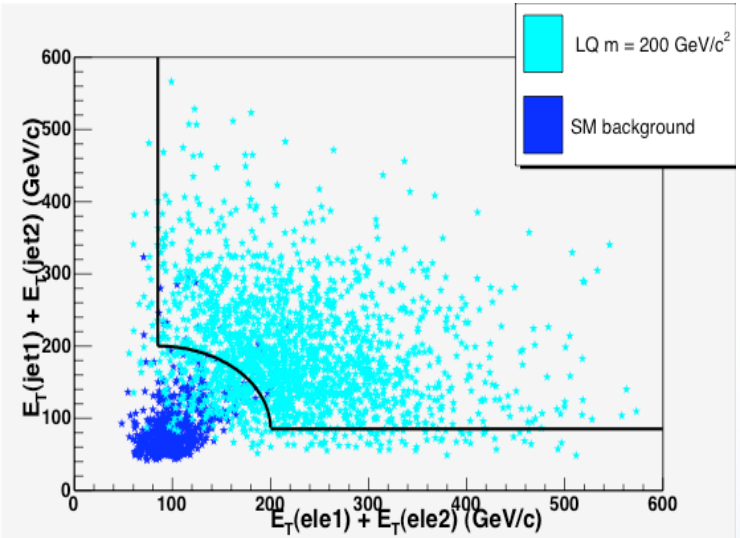
Search for LQ in dielectron + jets



SM background
- Drell-Yan+2jets
- Top ($W \rightarrow e\nu$)
- QCD/Fakes

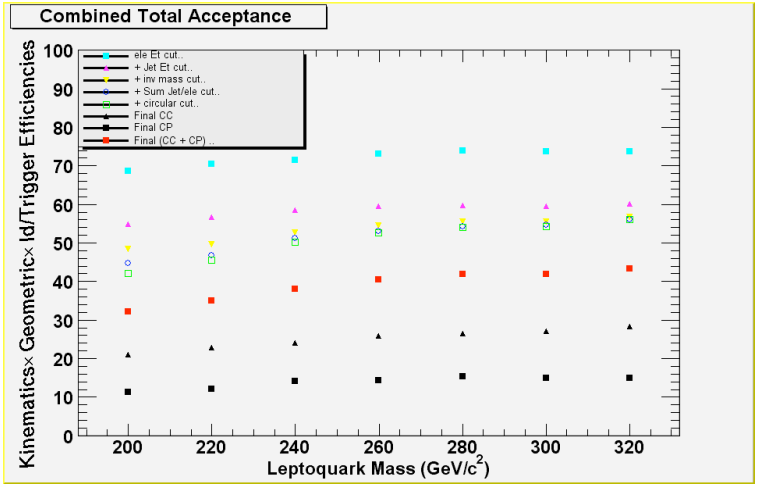
Selection

- ✓ 2 electrons (CC,CF) $E_T > 25$ GeV
- ✓ 2 jets, $E_T(j1) > 30$ GeV, $E_T(j2) > 15$ GeV
- ✓ Z Veto ($76 < M_{ee} < 110$) GeV
- ✓ Electrons/Jets: $E_T^{j1(e1)} + E_T^{j2(e2)} > 85$ GeV
- ✓ $((E_T(j_1) + E_T(j_2))^2 + (E_T(e_1) + E_T(e_2))^2)^{1/2} > 200$ GeV



<u>Control Sample: Z + 2 jets</u>
138 events after the 2 jets cut
107 in the Z mass window (66-116)
Predicted: 111 ± 15

Search for LQ in dielectron + jets(ll)



Backgrounds:	eejj
Z + 2 jets (alpgen)	1.89 ± 0.44
ttbar (Pythia)	0.35 ± 0.03
Fakes (data)	3.96 ± 2.01
Total	6.24 ± 2.16
Observed	4

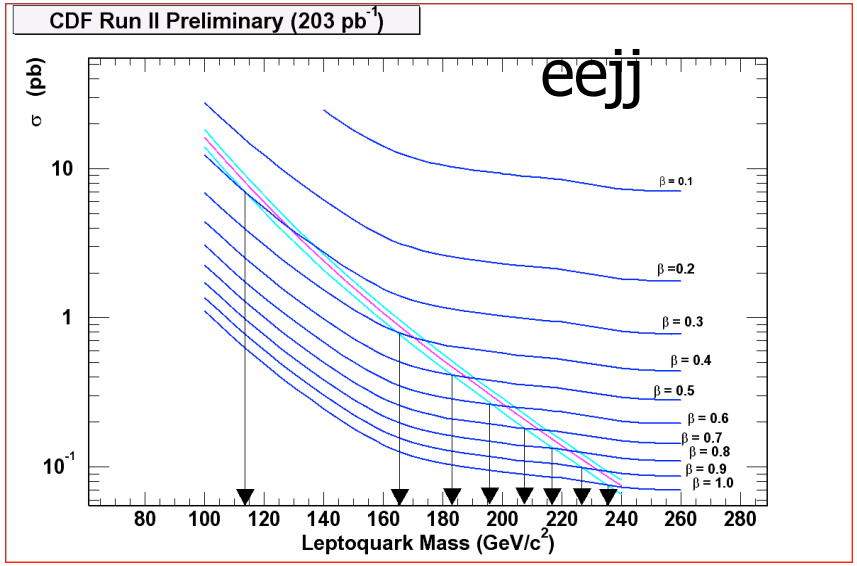
Systematics: signal acceptance and background prediction

Luminosity	6%
pdf	2.1%
statistics of MC	~1.2%
Jet Energy Scale	<1%
ele id	<1%
Z vertex cut	0.5%

Search for LQ in dielectron + jets (III)

TABLE III: 95% C.L. lower limits on the first generation scalar leptoquark mass (in GeV/c^2), as a function of β.The limit from CDF[7] ($eejj$) Run I ($\sim 120 pb^{-1}$) is also given.

β	ee jj	$e\nu jj$	$\nu\nu jj$	Combined	CDF Run I
0.01	-	-	116	126	-
0.05	-	-	112	134	-
0.1	-	144	-	145	-
0.2	-	158	-	163	-
0.3	114	167	-	180	-
0.4	165	174	-	193	-
0.5	183	176	-	205	-
0.6	197	174	-	215	-
0.7	207	167	-	222	-
0.8	216	158	-	227	-
0.9	226	144	-	231	-
1.0	235	-	-	236	213

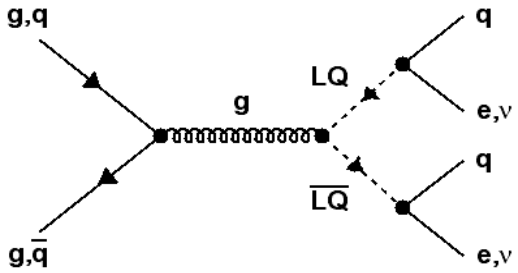


Other β limits are obtained using partial information on the acceptance

This analysis is optimized for β = 1

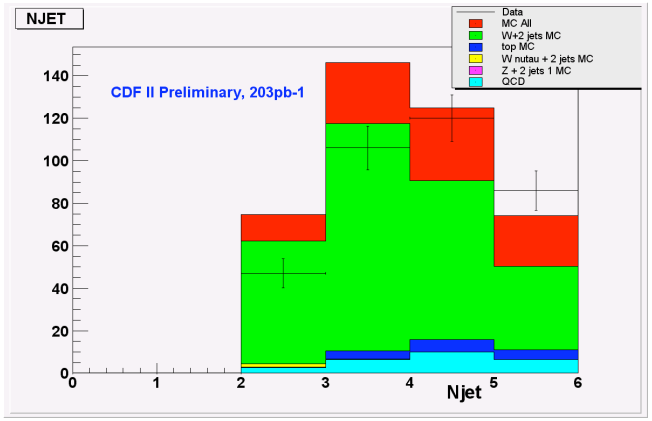
Exclude at 95% CL M_{LQ}<235 GeV/c^2

Search for LQ in electron + MET + jets



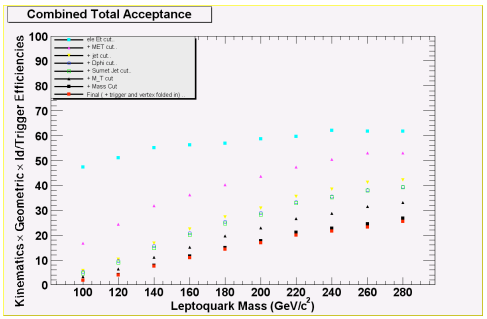
SM background

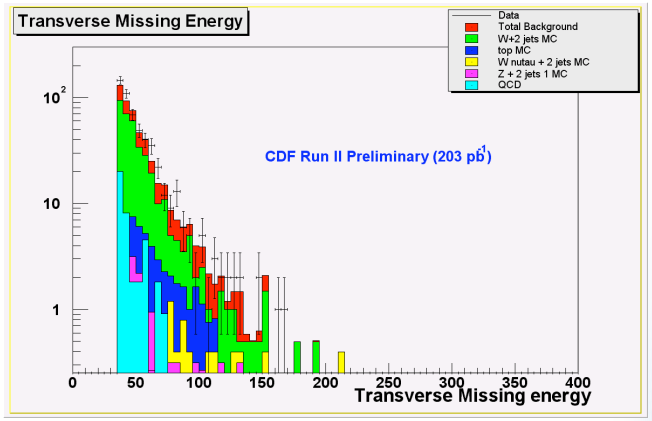
- W +2jets
- Top (l + jets and dilepton)
- QCD/Fakes



Selection

- 1central electrons with E_T > 25 GeV
- MET > 60 GeV
- Veto on 2nd electron, central loose or Plug
- 2 jets with E_T > 30 GeV
- $\Delta\phi$ (MET-jet) > 10°
- $E_T(j1) + E_T(j2)$ > 80 GeV
- $M_T(e\text{-}\nu)$ > 120
- LQ mass combinations



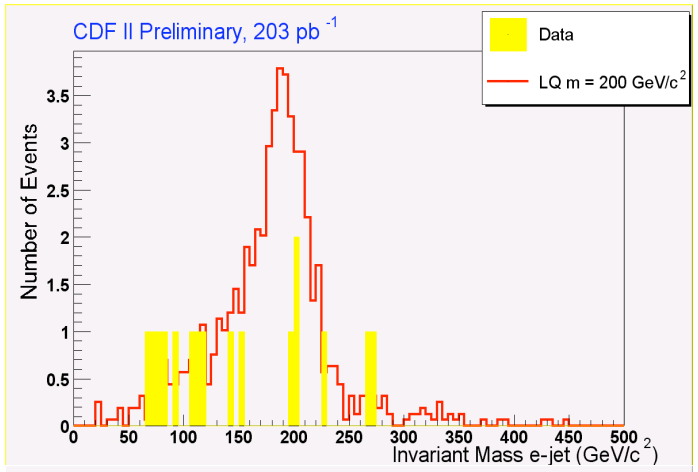


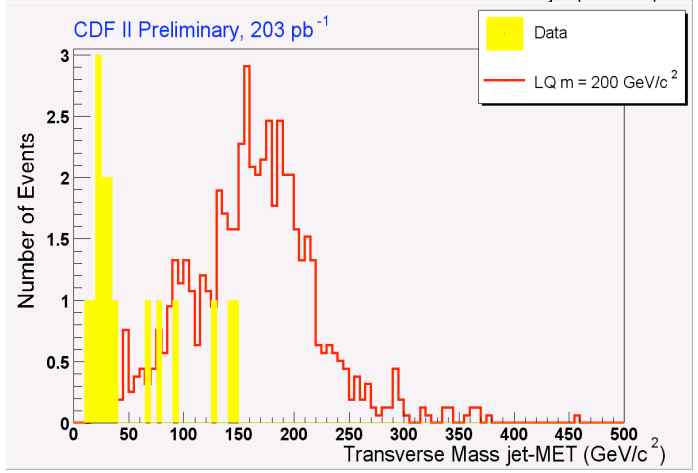
W + 2 jets control sample

Search for LQ inelectron,MET + jets (II)

TABLE II: Final number of events surviving all cuts in the electron, missing energy and jets topology, compared with background expectations, as function of the LQ mass (in GeV/c^2).

Mass	W + 2 jets	top	Z + 2 jets	Total	Data
120	1.5 ± 0.9	3.3 ± 0.5	0.06 ± 0.01	4.9 ± 1.0	6
140	1.5 ± 0.9	3.1 ± 0.6	0.08 ± 0.02	4.7 ± 1.0	4
160	2.5 ± 1.1	2.8 ± 0.6	0.08 ± 0.02	5.4 ± 1.2	4
180	2.5 ± 1.1	2.4 ± 0.5	0.08 ± 0.02	5.0 ± 1.2	4
200	2.5 ± 1.1	2.0 ± 0.5	0.07 ± 0.02	4.6 ± 1.2	4
220	2.0 ± 1.0	1.6 ± 0.3	0.06 ± 0.02	3.7 ± 1.1	2
240	2.0 ± 1.0	1.1 ± 0.3	0.06 ± 0.02	3.1 ± 1.0	2
260	1.5 ± 1.0	0.8 ± 0.3	0.04 ± 0.02	2.4 ± 0.9	2





Systematics: signal acceptance and background estimate

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Statistics of MC	~1.2%
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Z vertex cut	0.5%

Search for LQ in electron,MET + jets (III)

TABLE III: 95% C.L. lower limits on the first generation scalar leptoquark mass (in GeV/c^2), as a function of β.The limit from CDF[7] ($eejj$) Run I ($\sim 120 pb^{-1}$) is also given.

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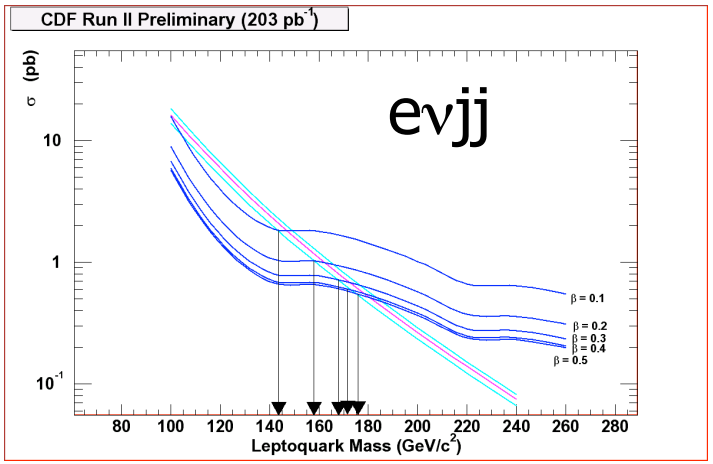


This analysis is optimized for β = 0.5

Other β limits are obtained using partial information on the acceptance

Exclude at 95% CL M_{LQ}<176 GeV/c^2

Combined Limit

Joint likelihood formed from the product of the individual channels likelihood. The searches in the dileptons and lepton + MET channels use common criteria and sometime apply the same kind of requirements (for example on lepton identification) so the uncertainties in the acceptances have been considered completely correlated (which gives the most conservative limit). When calculating the limit combination including also the $\nu\nu jj$ channel the uncertainties in the acceptances have been considered uncorrelated.A correlation factor of 0.5 has also been considered (no difference)

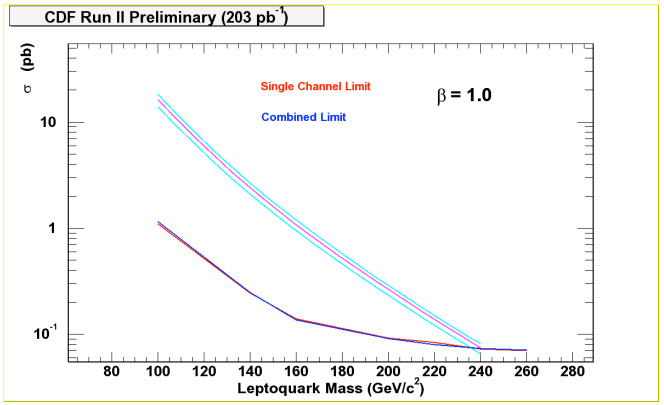
$$\sigma_{LIM} = N_{LIM}/(\varepsilon_{average} \times \mathcal{L})$$

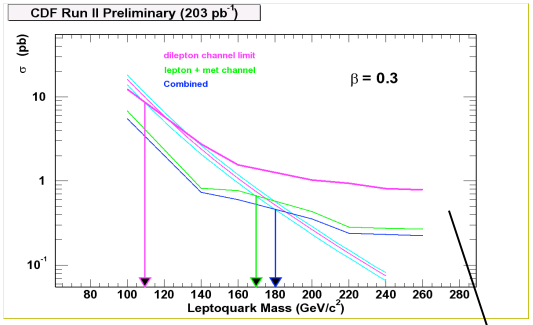
$$\varepsilon_{average} = (\beta^2\varepsilon(eejj) + 2\beta(1-\beta)\varepsilon(e\nu jj) + (1-\beta)^2\varepsilon(\nu\nu jj) + \beta^2\varepsilon(ee \text{ as } e\nu))$$

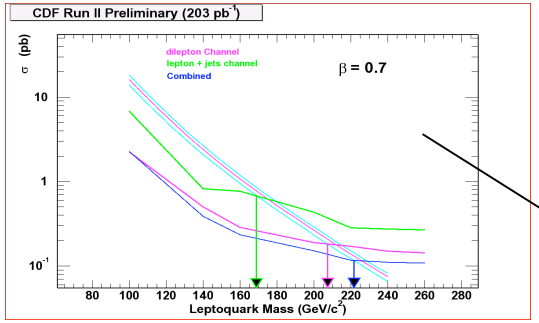
This is the correct efficiency for ALL β

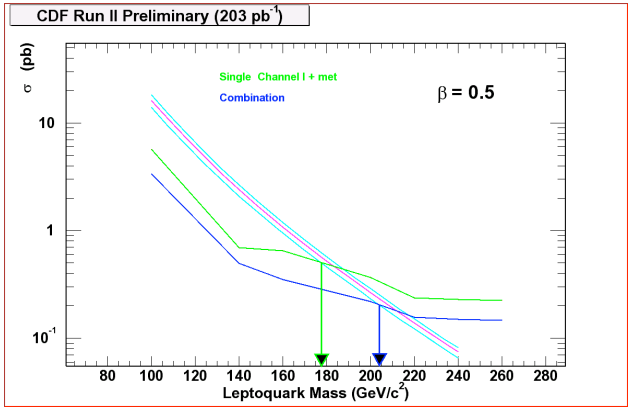
Single channel limits are obtained using efficiency optimal ONLY for $\beta = 1$ and $\beta = 0.5$. All other β values are extrapolations in the absence of complete information

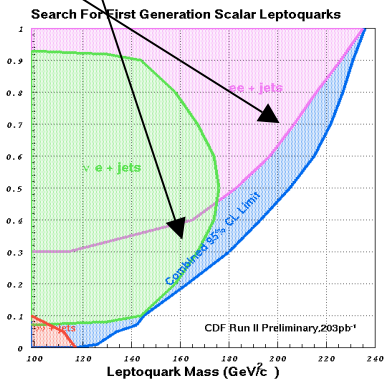
Combined Limit (II)











Final Result

TABLE III: 95% C.L. lower limits on the first generation scalar LQ mass (in GeV/c^2), as a function of β. The limit from CDF[7] ($eejj$) Run I ($\sim 120 pb^{-1}$) is also given.

β	ee jj	$e\nu jj$	$\nu\nu jj$	Combined	CDF Run I
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0.2	< 100	158	< 80	163	-
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0.4	165	174	< 80	193	-
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0.6	197	174	< 80	215	-
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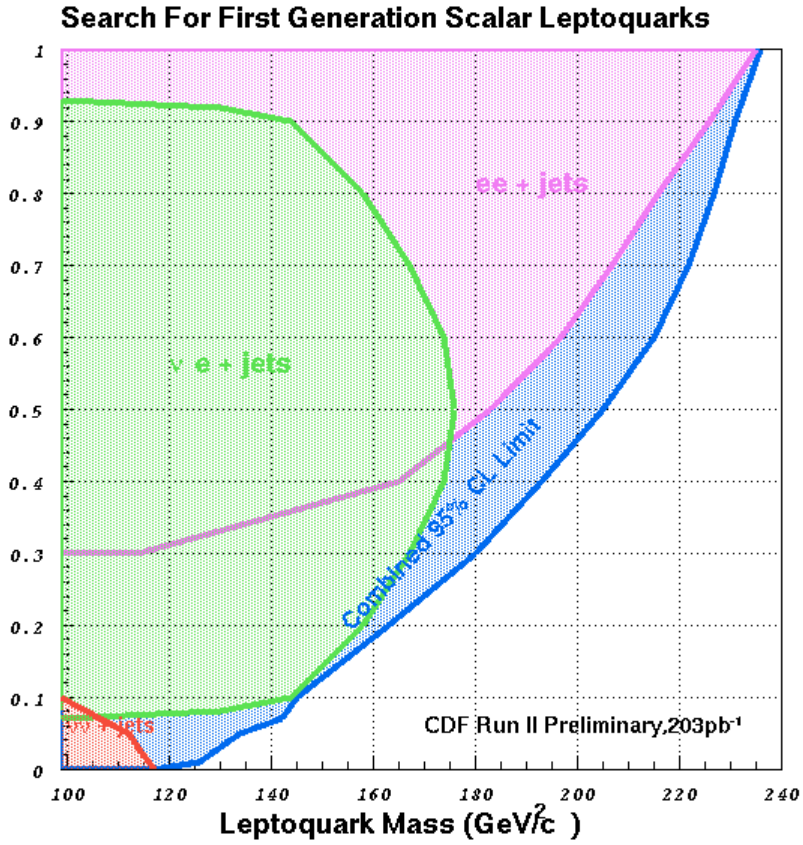
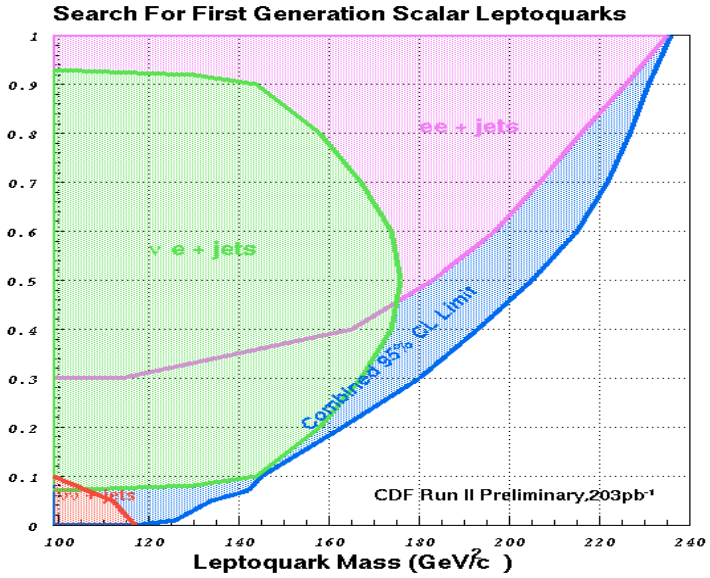


Conclusions

- We have performed a search for first generation scalar letpoquarks using Run II data.
  - All β channels have been included (Run I only the β =1 result was published)
  - All channels have been combined (no Run I analogous result)
- No LQ's observed …
- 95% CL mass limits for as a function of β:



Aknowledgments

Thanks to the Exotic Conveners, especially Stephan Lammel!

Thanks to the GP's, Frank Chlebana, Allan Clark and Lucio Cerrito!

Thanks to the Run I predecessors:
Carla Gross-Pilcher, Federica Strumia and Lorenzo Moneta !

Thanks to the reading institutions!

Thanks for all the other comments and suggestions!
http://fcdfwww.fnal.gov/internal/physics/lq_search/

Backup Slides

GP's and references

GP's are:
Frank Chlebana (FNAL, chair)
Allan Clark (Geneva)
Lucio Cerrito (Oxford)

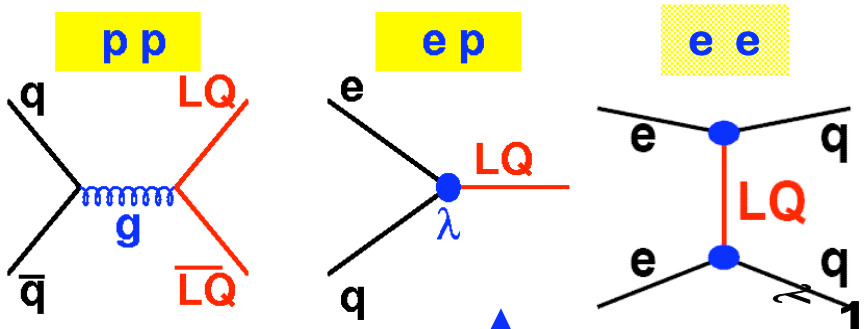
Web page at:
http://fcdfwww.fnal.gov/internal/physics/lq_search/

Efficiencies

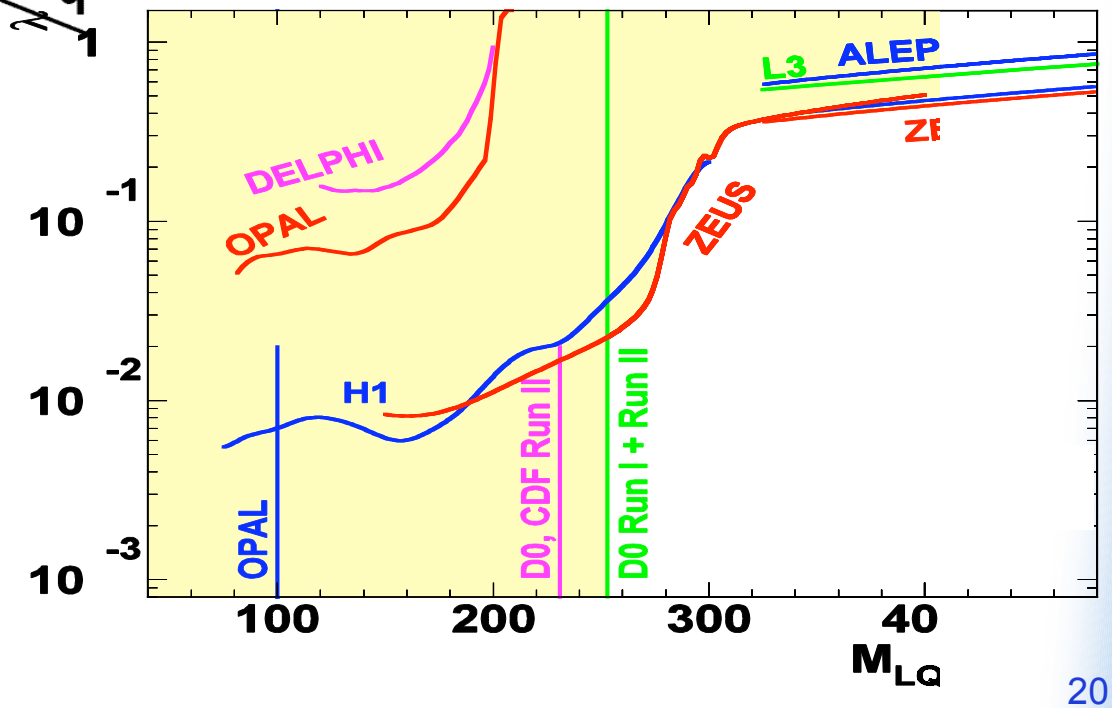
TABLE I: Efficiencies after all cuts with total error (statistical and systematic) and 95% C.L. upper limits on the production cross section × branching fraction Br, as a function of M_{LQ}, for the two channels.

M_{LQ} (GeV/c^2)	$eejj$		$e\nu jj$	
	ϵ (%)	$\sigma \times \mathrm{Br}$(pb)	ϵ (%)	$\sigma \times \mathrm{Br}$(pb)
100	7 ± 0.5	1.11	2 ± 0.26	5.71
140	12 ± 0.5	0.25	8 ± 0.7	0.69
160	21 ± 0.8	0.14	8 ± 0.7	0.65
200	32 ± 1.2	0.09	16 ± 1.3	0.37
220	35 ± 2.0	0.08	19 ± 1.5	0.24
240	38 ± 2.0	0.07	20 ± 1.6	0.23
260	40 ± 2.0	0.07	22 ± 1.7	0.22

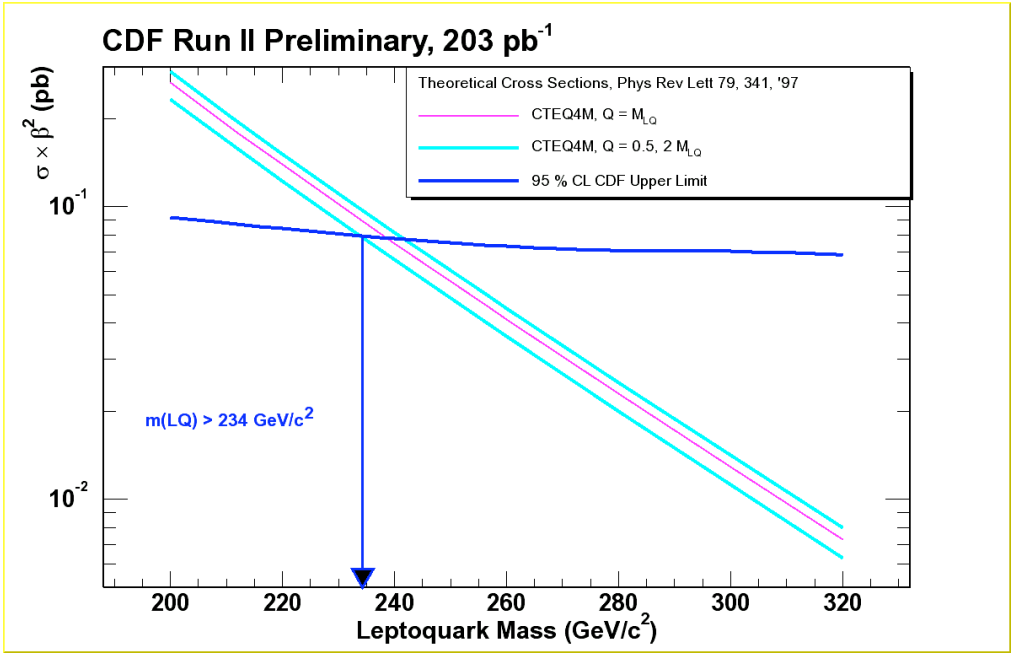
Comparison with Other Colliders



λ dependence



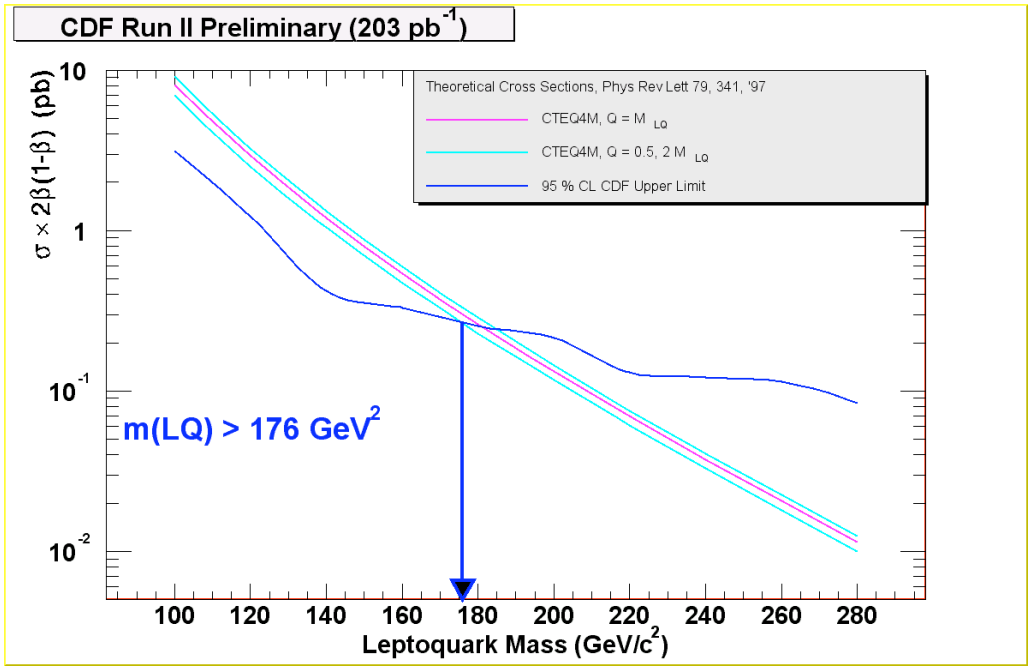
CDF - ee channel



Luminosity 203pb^{-1}

Exclude at 95% CL M_{LQ}<235 GeV/c^2

CDF – eνjj Channel



Luminosity 203pb^{-1}

Exclude at 95% CL M_{LQ}<176 GeV/c^2

eνjj - Mass combination

The peak of the *ej* histogram is fitted with a gaussian

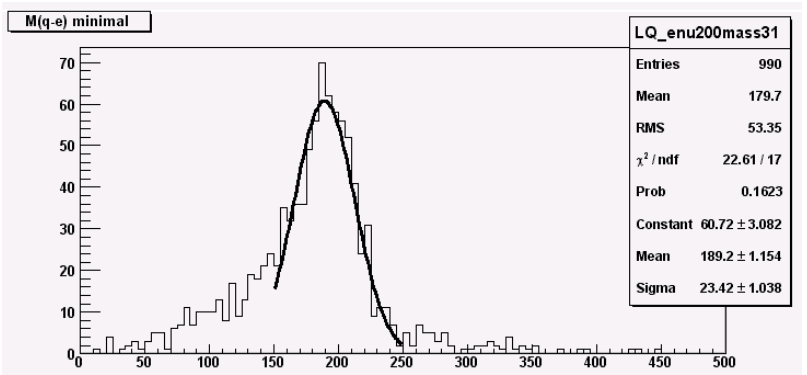
rough estimate of the spread of the distribution in the signal region.

Several masses (120-160-200-240-280) tested:

$\sigma_e \sim 15\%$.

The ν-q transverse mass distribution is fitted including the high mass tail end, with a Gaussian to estimate the signal spread.

$\sigma_\nu \sim 25\%$.



3σ cut around the nominal mass to select LQ candidates of a given mass

At the End of TeVatron Run II

Assumptions:

Same acceptances as now

Number of events observed = number of predicted background

Same errors

$\beta = 1$ mass limit up to 250-300 GeV/c^2

$\beta = 0.5$ mass limit up to 230-280 GeV/c^2

Preliminary

New analysis strategy
(not counting experiment anymore?)
might be necessary.....